Renewable and Sustainable Energy Reviews 18 (2013) 119–133

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Assessments and perspectives of PV solar power engineering in the Republic of Srpska (Bosnia and Herzegovina)

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ARTICLE INFO

Article history:
Received 7 September 2011
Received in revised form
5 October 2012
Accepted 8 October 2012

Keywords:
Solar energy
Photovoltaic systems
Photovoltaic in Bosnia and Herzegovina
Climatic characteristics of the Republic of Srpska
Photovoltaic in the Republic Of Srpska

ABSTRACT

The paper focuses on the possibilities of generating electrical energy by means of on-grid PV solar systems of 1 kW in the Republic of Srpska (Bosnia and Herzegovina). The paper proceeds to tackle with the legislative concerning renewable sources of energy and current state of the use of PV systems in the Republic of Srpska and Bosnia and Herzegovina, climate conditions and energy potential of the renewable sources in the Republic of Srpska. Based on PVGIS program, the results of calculation of the yearly average values of the optimal panel inclination, solar irradiation on the horizontal, vertical and optimally inclined plane, ratio of diffuse to global solar irradiation, linke turbidity, average daytime temperature and 24 h average of temperature for 13 cities in the Republic of Srpska are given. Total for year sum of global irradiation per square meter received by the modules of the optimally inclined fixed PV solar plants of 1 kW, optimally inclined one-axis and dual-axis tracking PV solar plants of 1 kW, and total for year electricity production of different types of PV solar plant of 1 kW for 13 cities in the Republic of Srpska, obtained by PVGIS are given. Comparison of the total for year electricity production of different types of PV solar plant of 1 kW with monocrystaline silicon, CdTe and CIS solar modules, respective, to 13 cities in the Republic of Srpska are given. Calculations performed by PVGIS program have shown that irrespectable of the type of PV solar plants, most electrical energy in the Republic of Srpska can be generated by means of PV solar plants with CdTe solar cells. Some practical data and considerations given in this paper can be used by a customer or company keen to invest in the PV sector in the Republic of Srpska.

Contents

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1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2012.10.007

1. Introduction

Economic development of countries at the end of the 19th and in the beginning of the 20th century was based on the consumption of enormous quantities of non-renewable sources of energy such as coal, oil and nuclear fuel. However, limited reserves of non-renewable sources of energy will in the near future make most of the countries in the world face serious shortages of energy. Enormous consumption and increase of the world's population will force this same population in large number of countries to handle the problem of the critical decrease in supplies of the domestic fossil fuels. Current energy dependence of most countries on the oil and its derivatives calls for profound economic expenditures and in future heralds negative effects on the national economies and the international safety situation [1–3].

According to the available data total world oil consumption is almost 4 billion of tons a year, while the total reserves are around 120–160 billion of tons. Taking into account limitations of the supplies, current use of the fossil and nuclear fuels cannot provide for the long term sustainable development. Since the reserves of the fossil fuels are vanishing rapidly in the successive two decades most countries will be forced to use renewable sources of energy to meet their needs for the energy. Extensive body of research has shown that natural and technical potential of the renewable sources of energy is sufficient to meet the needs for energy of the whole world population, since their natural daily potential is 20,000 times higher than a daily consumption of the nuclear and fossil fuels. Since it is all about relatively new technologies, there is an enormous potential for their further technological improvements and new applications. Energy sector based on fossil fuels and nuclear energy still obtains ten times higher governmental subsidies for research and development compared to the technologies of the renewable sources of energy. In the industrialized countries only 7% of the total funds for the research and development is alloted for the renewable sources of energy compared to 70% for the research and development of the nuclear and other technologies [1,2,4].

In the paper [5] the world primary energy demand projection in the Reference Scenario to expand by almost 60% from 2002 to 2030, which is an average annual increase of 1.7% per year, is given. This demand will reach 16.5 billion tons of oil equivalents (toe) compared to 10.3 billion toes in 2002. On the other hand, fossil fuels will dominate global energy use. They will account for around 85% of the increase in world primary demand over 2002–2030. Their share in total demand will increase slightly, from 80% in 2002 to 82% in 2030. The share of renewable energy sources will remain flat, at around 4%, while that of nuclear power will drop from 7% to 5% [5].

In order to increase the use of the renewable sources of energy their technological development worldwide should be given much higher political and economic priority and emphasis. Burning of the fossil fuels, especially those based on the oil and coal, presents most probable cause of the global warming and creation of the green house effects. Change of the climatic conditions presents one of the most serious dangers for the earth's ecological system due to the possible influence on the production of food and key processes that create productive natural environment. Alarming increase of the emission of carbo dioxide into the atmosphere, among other factors, can decrease the dependence on the use of coal and can encourage the development and use of renewable sources of energy technologies. Although the use of fossil fuels per capita is decreased due to the measures taken to preserve the natural resources, the increase of the population in the world brings about more rapid decrease in the supplies of the fossil fuels and the increase of the global warming. Also, due to the above mentioned reasons the estimation of the current energy situation in the world is inadequate, that is, the reserves of the fossil fuels are probably overestimated. Significant reduction of the consumption of the fossil fuels by more efficient use of energy and the use of solar and other renewable sources would prolong the exploitation of the fossil sources of energy on the one hand, and could provide for the time necessary to develop and improve the technologies to use the renewable sources of energy on the other hand [1,2,6,7]

The Solar Energy sector in the Republic of Srpska, and generally in Bosnia and Herzegovina is not developed yet. This paper focuses on the possibilities of generating electrical energy by means of on-grid PV solar systems of 1 kW in the Republic of Srpska (Bosnia and Herzegovina).

The aim of this paper is to report structure, properties, benefits and life of photovoltaic systems. Calculations performed by PVGIS program that we have compared the type of PV solar plants could be used also for developing countries.

2. Advantage of solar energy and photovoltaic technologies

The paper [8] claims that in 2005 worldwide electricity generation was 17 450 TWh, out of which 40% originated from coal, 20% from gas, 16% from nuclear, 16% from hydro, 7% from oil and only 2% from renewable sources such as geothermal, solar, wind, combustible renewables and waste. The current fuel mix has fossil and nuclear fuels contributing to nearly 70% of the total generation [8].

Energy, which is the main agenda of our world, is crucially important for the humanity. Many countries frequently tackle the problem of energy in order to balance the energy demand and supply. Therefore, extensive research should be attempted to present a more efficient way to use energy and renewable energy resources effectively [9].

In ancient times, the Sun was worshiped as a life-giving planet. Later, as education and the industrial age progressed, knowledge of the Sun as energy source was more comprehended. The importance of such a discovery reached its peak in the current era, where the extraction of fossil fuel for energy production has been proven to affect the planet's ambient temperature. The paper [10] cites that each day the Sun provides 10,000 times more energy than the energy needed on the planet. Water, bioenergy, or wind powers were all sources used in the early human societies and they are, in one way or another, derived from solar power. Technologies which can harness the power of the sun continued to improve right up to the early years of the industrial revolution. Since then, as communities developed activities, green house gases, in particular carbon dioxide (CO_2) emissions increases, causing global warming, a factor causing temperature rise of 0.6 °C. Future predictions indicate that surface temperature could increase from 1.4 °C to 5.8 °C, if any action is not taken. Such developments will probably cause droughts, floods, sea level rise, glacier melting, and serious disruptions to agriculture and natural ecosystems, so the urgent consensus is needed to reduce such emissions. This reduction of emissions can be achieved by

switching many traditional energy applications to renewable energy technologies [10].

Solar energy is the most abundant, inexhaustible and cleanest of all renewable energy resources to date. The power from the Sun intercepted by the Earth is about 1.8×10^{11} MW, which is many times larger than the present rate of all the energy consumption [11].

Solar energy is one of the best renewable energy sources with least negative impacts on the environment. Different countries have different solar energy policies to reduce dependence on the fossil fuels and increase domestic solar energy powered energy production. The paper in Ref. [5] gives a review about different solar energy policies implemented in different countries in the world. According to the 2010 Statistical Energy Survey, the world cumulative installed solar energy capacity was 22,928.9 MW in 2009, a change of 46.9% compared to 2008. Based on an extensive body of literature, it has been found that feed-in tariff (FIT), renewable portfolio standard (RPS) and incentives are the most beneficial energy policies implemented by many countries around the world. These policies provide significant motivation and interest for the development and use of renewable energy technologies [5].

Currently, solar energy conversion is widely used to generate heat and produce electricity. The paper in Ref. [6] gives a comparative study on the world energy consumption released by International Energy Agency (IEA) which shows that in 2050, solar array installations will supply around 45% of the energy demand in the world.

A main argument to support and emphasize the use of solar energy is that it represents a universally available, renewable energy source, which is not directly linked to political and environmental factors associated with the global market for oil and other fossil fuels. In the ranking of renewable energies drawn up in paper [8]; PV lags behind other renewable energies, mainly due to the low efficiency of the current technology, which implies a higher price for electricity. The existence of feed-in tariff systems is an attempt to overcome this problem. It demonstrates institutional interest in encouraging the implementation of PV installations and has led to a proliferation of such plants, so much so that in the past two years, the price per kW installed has been reduced by almost half, according to the paper [12].

Solar energy is obviously environmentally advantageous in comparison to any other energy source, it is the milestone of any serious sustainable development program. It does not deplete natural resources, does not cause CO_2 or other gaseous emission into air, nor does it generate liquid or solid waste products. The paper in Ref. [5] explains that, concerning sustainable development, main directly or indirectly derived advantages of solar energy use are the following:

1. No emissions of green house (mainly CO_2, NOx) or toxic gasses (SO_2, particulates).
2. Reclamation of degraded land.
3. Reduction of transmission lines from electricity grids.
4. Improvement of the quality of water resources.
5. Increase of regional/national energy independence.
6. Diversification and security of energy supply.
7. Acceleration of rural electrification in developing countries, etc.

Due to this fact use of solar energy contributes to more efficient use of countries' own potentials in producing electrical and thermal energy, to the reduction of the emission of the green house gases, to the lowering of the import rates and the use of fossil fuels, to the development of the local industries and the increase of the job openings [2,5].

One of the most popular techniques of solar energy generation is the installation of photovoltaic (PV) systems using sunlight to generate electrical power. There are many factors affecting operation and efficiency of the PV based electricity generation systems, such as PV cell technology, ambient conditions and the selection of required equipment. There is scarce study that presents all factors affecting efficiency and the operation of the entire PV system. The paper in Ref. [13] provides a detailed review of these factors and also includes suggestions for the design of more efficient systems. The presented detailed overview will be useful to people working on theory, design and/or application of photovoltaic based electricity generation systems.

Photovoltaic technology is one of the finest ways to harness solar power. The paper [10] reviews photovoltaic technology, its power generating capability, different existing light absorbing materials used, its environmental aspect coupled with a variety of its applications. Also, different existing performance and reliability evaluation models, sizing and control, grid connection and distribution are given in the paper [11].

Ref. [10] gives a full review on the development of the existing photovoltaic (PV) technology. It highlights four major current types of PV: crystalline, thin film, compound and nanotechnology. The aim of the continuous development of PV technology is not only to improve the efficiency of the cells but also to reduce production costs of the modules, thus making it more feasible for various applications. Moreover, such variety in technology is needed to enhance deployment of solar energy for a greener and cleaner environment. Devices such as space PV cell technology were also described and the expanding progress in this field. In addition, a quick overview of the application of PV installations is described in the paper [10].

The importance of photovoltaic was once a questionable issue when fossil fuel was seen as an endless source of energy. However, with growing recognition of the environment impact and the economic instability due to oil and gas price fluctuations, photovoltaic development gained the interest of almost all sectors as can be seen in the paper [10]. Currently, PV market consists of a wide range of material and manufacturing processes leading to knowledge transfer regarding the efficiency and suitability of the available technologies. The 1st PV generation is governed by single-junction crystal solar cell based on silicon wafers (single and multi crystalline silicon). Second generation technologies are based on single junction devices aiming to optimize material usage whilst upholding the efficiencies achieved earlier. This generation comprises CdTe, CiGS and a-Si. While the 2nd PV generation emphasis is on the reduction of material cost by embracing thinner films, the 3rd PV generation approach is more concerned with double, triple junction and nanotechnology, all showing promising results of having more efficient cells at lower cost [10,14,15].

Photovoltaic energy power systems are considered to be most dominant technology among renewable energy technologies. Most important reason is that it is unlimited and the cleanest energy of the solar power systems. Many studies show that photovoltaic power systems will have an important share in the electricity of the future. Among various solar energy technologies of sustainable energy sources, photovoltaic (PV) appears quite attractive for electricity generation because it is noiseless, has no carbon dioxide emission during operation, shows scale flexibility and are rather simple to operate and maintain. The photovoltaic (PV) power system has received considerable attention for the clean energy resource to solve the environmental problem on the worldwide scale. One key argument for an accelerated deployment of renewable energies in general, and PV in particular, is besides environmental benefits, the avoided risk of disruption in fossil fuel supply, and of the associated price instability. Therefore

renewable energies have a significant contribution towards supply security [2,9,15].

The electricity from photovoltaic cells can be used for a wide range of applications, from power supplies for small consumer products, to large power stations feeding electricity into the grid. Ref. [9] states that the world photovoltaic industry has shown an average growth rate of 49.5% over the past 5 years. World solar photovoltaic (PV) market installations reached a record high of 5.95 GW in 2008, representing growth of 110% over the previous year. Solar energy, including solar photovoltaics (PVs), has a vast sustainable energy potential in comparison to the global energy demand. The IEA envisaged solar power accounting for 11% of global electricity production by 2050 and solar electricity contributes about 20% of the world's energy supply by 2050 and over 60% by 2100. It is clear that electricity generation with PV cells will play an important role in the future of the energy. PV systems developments will increase and focus more and more on the PV industry that is poised for exponential decrease in their cost. This development will make its major breakthrough in few years [9,15].

Price profiles for each non-combustion renewable energy technology show high capital intensity and low running costs, due to zero fuel requirements. For photovoltaics, the most significant cost is silicon purification, using 60% of the production energy of a frameless multi-crystalline module. Overall capital costs account for over 95% of the life cycle costs for photovoltaics, meaning that interest rate variations have a large impact on life cycle prices. This would be expected with all other capital-intensive technologies. Wind costs can be minimized by careful selection of suitably sized generators, according to the quality of the site-specific wind resource. Hydro dam construction accounts for nearly all hydro costs, with the low operation, maintenance and refurbishment costs and long plant lifetimes. Geothermal prices are heavily increased by the long project development times, high costs and risk of exploratory drilling. Drilling can account for up to 50% of the total project cost. Wide-ranging values for the price per kWh are seen for all technologies, however the greatest range is for photovoltaics. For each technology, the average value was much closer to the lowest than the highest price. Hydro had the lowest average cost, geothermal and wind the same average cost with geothermal exhibiting lower range in price variations. Photovoltaics are the most expensive technology [8,14].

Photovoltaics have low emissions, with average reported values of less than 100 g/kWh CO_{2-e}. Photovoltaic efficiency is highly variable due to the large range of cell types available, with an ideal cell efficiency of 30%. Crystalline silicon cells (including multi- and poly-crystalline) have the highest efficiencies and amorphous silicon the lowest [8].

Solar cells offer an attractive source of power without fuel dependence, the need for conventional power plants and reduced mining. The manufacture of solar cells involves several toxic, flammable and explosive chemicals. With constantly reduced mass requirements during cell manufacture due to thinner cells, masses involved and hence risks are reduced, however, all chemicals must be carefully handled to ensure minimal human and environmental contact. Solar farm locations must be carefully selected to reduce competition with agriculture, soil erosion and compaction [2,8,16,17].

3. PV solar systems

The PV solar system means a system by which the solar irradiation is converted into the electrical energy and is distributed to the direct and/or alternating current consumers. PV solar system can function independently of the electric power network (off grid) or it can be connected to it (on grid). Depending on the components that comprise it, off grid PV system can supply the consumers with DC current or AC current. Off grid PV system that gives consumers DC current is composed of solar cells, batteries and batteries charge controllers. Off grid PV system that provides consumers with AC current consists of solar cells, battery charge controllers, batteries and DC to AC inverter. On grid PV system consists of solar cells, inverter, monitoring system, distribution boxes, switches and related connections. On grid PV system are most frequently used for PV solar plants, residential and office buildings, etc. [13,16–18].

PV solar plant denotes a plant using solar cells to convert solar irradiation into the electrical energy. PV solar plant consists of solar modules, inverter converting DC into AC and transformer giving the generated power into the grid net. PV solar plant is fully automatized and monitored by the applicable software. PV solar plants mostly use solar modules made of monocrystalline and polycrystalline silicon, and rarely, modules made of thin film materials such as amorphous silicon, CdTe and Copper–Indium–Diselenide (CIS, $CuInSe_2$). Efficiency of the commercial monocrystalline silicon solar cells is 15%, of polycrystalline silicon is around 12%, of amorphous silicon is around 5% and from CdTe and CIS is around 8%. Monocrystalline and polycrystalline silicon solar modules are more suitable for the areas with predominantly direct sun radiation, while solar modules of thin film are more suitable for the areas with predominantly diffuse sun radiation [2,13,14,16,17,19,20].

Practice shows that the energy efficiency of PV solar plant annually decreased from 0.5–1%. The lifetime of PV modules depends on the solar cell technology used as well. For monocrystalline and polycrystalline silicon solar cells most manufacturers give a warranty of 10/90 and 25/80 which means: a 10-year warranty that the module will operate at above 90% of nominal power and up to 25 years above 80%. The practical lifetime of the silicon-made PV modules is expected to be at least 30 years [2,16,17,21].

PV solar plants represent environmentally clean source of energy. PV solar plant components (solar modules, inverters, monitoring system, conductors, etc.) are manufactured by cutting edge, environmentally friendly technologies. PV solar plants operate noiseless, do not emit harmful substances and do not emit harmful electromagnet radiation into the environment. PV solar plant recycling is also environmentally friendly. For 1 kWh of PV solar plant generated electrical energy emission of 0.568 kg CO_2 into the atmosphere is reduced [2,8,16,17].

Depending on the climate conditions of given location fixed PV solar plants, one-axis and dual-axis tracking PV solar plants are being installed worldwide. Fixed PV solar plants are used in regions with continental climate and tracking PV solar plants are used in tropical regions [2,16,17].

Fixed PV solar plant denotes plant with solar modules mounted on fixed metal supporters under optimal angle in relation to the horizontal surface, and all are oriented towards south. One-axis tracking PV solar plant denotes a plant where solar modules installed under the optimal angle are adapted towards the sun by revolving around the vertical axis during the day from the east towards the west, following the Sun's azimuth angle from sunrise to sunset. Dual-axis tracking PV solar plant denotes a plant where the position of solar modules is adapted towards the sun by revolving around the vertical and horizontal axis. These PV solar plants follow the Sun's azimuth angle from sunrise to sunset but, they also adjust the tilt angle to follow the minute-by-minute and seasonal changes in the Sun's altitude angle [2,16,17,22,23].

The diurnal and seasonal movement of earth affects the radiation intensity on the solar systems. Sun-trackers move the

solar systems to compensate for these motions, keeping the best orientation relative to the sun. Although using sun-tracker is not essential, its use can boost the collected energy 10–100% in different periods of time and geographical conditions. However, it is not recommended to use tracking system for small solar panels because of high energy losses in the driving systems. It is found that the power consumption by tracking device is 2–3% of the increased energy [22].

Practice showed that the yearly optimal tilt-angle of a vertical-axis tracked solar panel for maximizing the annual energy collection was almost linearly proportional to the site latitude, and the corresponding maximum annual collectible radiation on such tracked panel was about 96% of solar radiation, annually collected by a dual-axis tracked panel. Compared with a traditional fixed south-facing solar panel inclined at the optimal tilt-angle, the annual collectible radiation due to the use of the vertical-axis sun-tracking was increased by 28% in the areas with abundant solar resources, and was increased by 16% in the areas with poor solar resources [23].

4. Administrative subdivisions of Bosnia and Herzegovina

Bosnia and Herzegovina has several levels of political structuring under the federal government level which are important to be considered in order to make some recommendations for country policies and financial support.

Most important of these levels is the division of the country into two entities: Republic of Srpska and the Federation of Bosnia and Herzegovina. The Brcko district, in the north of the country, was created in 2000 out of land from both entities. It officially belongs to both, but is governed by neither, and functions under a decentralized system of local government. The third level of Bosnia and Herzegovina's political subdivision is the cantons. They are unique to the Federation of Bosnia and Herzegovina entity, which consists of ten of them. The fourth level of political division in Bosnia and Herzegovina is municipalities. The Federation of Bosnia and Herzegovina is divided into 74 municipalities and the Republika Srpska in 63. Municipalities also have their own local government, and are typically based around the most significant city or place in their territory. Besides entities, cantons, and municipalities, Bosnia and Herzegovina also has four "official" cities. These are: Banja Luka, Mostar, Sarajevo, and East Sarajevo. The territory and government of the cities of Banja Luka and Mostar corresponds to the municipalities of the same name, while the cities of Sarajevo and East Sarajevo officially consist of several municipalities. Cities have their own city government whose power is in between that of the municipalities and cantons (or the entity, in the case of the Republika of Srpska) [24].

Map of the Republic of Srpska is given in Fig. 1.

4.1. Renewable energies policies in Bosnia and Herzegovina

At the state level no energy or environmental ministry/agency exists. Environment and energy fall under the responsibility of the Ministry of Foreign Trade and Economic Relations. At the entity levels the Ministry of Energy, Mining and Industry of the Federation of Bosnia and Herzegovina and the Ministry of Economy, Energy and Development of the Republika of Srpska are responsible for energy. Although a report on the institutional, regulatory and normative frameworks and a report on the strategy for the development of solar energy in Bosnia and Herzegovina will deal with this issue, it is important, in this renewable energy (RE) financing context analysis, to consider the RE currently established policies. In this sense, Energy Strategy is being developed

Fig. 1. Map of the Republic of Srpska.

through the EC CARDS Program as a "Technical Assistance to Support the Energy Department of Ministry of Foreign Trade and Economic Relations in B&H". As a first step, a comprehensive background energy sectors study towards the national energy strategy, is in a preparation phase, financed by the World Bank [24,25].

There are no official plans for the promotion of RE sources and for the increase in the energy efficiency. Nevertheless, a tariff system for RES electricity exists and the decision on methodology for the determination of purchase prices of electric power from RES up to 5 MW was adopted (Of. Gazette FB&H 32/2002, Of. Gazette RS 71/2004) [26]. Two power utility companies in Bosnia and Herzegovina are obliged to take over the electricity produced from RES. According to these decisions, the tariff systems for RES electricity are

1. Small Hydro plants: 3.96 €cents/kWh.
2. Landfill biogas and biomass plants: 3.81 € cents/kWh.
3. Wind and geothermal plants: 4.95 €cents/kWh.
4. Solar power plants: 5.44 €cents/kWh.

Financing incentives do not exist, neither do specialized institutions, training and education activities.

There are some projects (USAID, UNDP) and associations of citizens (CETEOR, COOR, CENER, CEET) and also centers dealing with this issue within the Faculties of University in Sarajevo, Banja Luka, Tuzla, and Mostar. UNDP runs several Area Based Development programs in Bosnia and Herzegovina, which aim to re-establish viable multi ethnic communities in a sustainable manner, with the design of projects that involve several components such as reconstruction of housing and infrastructure, strengthening local government capacities, support to local economic development and job creation, and the development of civil society. Energy efficiency and renewable energy projects could be built on the structure already in place, lessons learned and expertise gained through the ABD programs. There is no official structure that could network municipalities in the field of Municipal Energy Efficiency but initiatives as the Municipal Network for Energy Efficiency (MUNEE) and the SUTRA Initiative (Sustainable Transfer to Return related Authorities) have been established; although the information about their activities should be brought into daylight. One final and important aspect, to be exposed in the next paragraph, is the BISE process awareness in which Bosnia and Herzegovina is involved [27].

Solar Energy sector is not developed yet. There is no structure or professional and academic organizations. Most of the actors involved in Solar Energy do it as a secondary or marginal activity. The private businesses are not structured to interact with the academic, professional and institutional sectors. Within the solar sector, the technology which is most developed in Bosnia and Herzegovina, is the Solar Thermal (companies, universities, etc.). There are almost no organizations involved in photovoltaic.

Architecture and Electrotechnical faculty in Sarajevo and Electrotechnical faculty in Banja Luka are involved in solar energy, in Bosnia and Herzegovina. At the Architecture faculty in Sarajevo solar energy is included and taught in the curricula of the following courses: Architectonic Physics, Bioclimatic Architecture and Architecture as Energetic System. Architecture faculty in Sarajevo and Electrotechnical faculty in Banja Luka solar energy is taught in the Departments for Electroenergy within several courses. In Tuzla there is a Center for Energy and Ecology that educates about the use of flat-plate solar collectors for water heating.

In Federation of Bosnia and Herzegovina there are several companies that are running in the line of solar energy (NARODNO GRIJANJE- Sarajevo, SBH COMPANY- Brčko Distrikt, TECHNOPLUS-Tuzla). Republic of Srpska has several companies dealing with solar energy: BEMIND (Banja Luka, email: bemind@inecco.net), KOMING (Gradiška, www.rskoming.net), KLENIK (Gradiška, klenik@blic.net), TOPLING (Prnjavor, topling@blic.net) and PAVLOVIC MONT (Banja Luka, usluge@pavlovic-mont.com). TECHNOPLUS and SBH Companies are the only ones (from the list) dealing with photovoltaics technology. SBH Company, which is fully dedicated to the Renewable Energy, has very large number of installations and extensive experience. They have installations in Bosnia, Croatia and Serbia as well [24].

In Bosnia and Herzegovina PV systems are basically used in Traffic flow meters and Hydrological stations.

In 2002, the Government adopted a resolution to promote the generation of electricity from renewable energy sources. In this, the electricity suppliers or grid operators are obliged to accept electricity from renewable energy sources in their grids and to pay a fixed rate for it. The level of remunerations for the in-feed of electricity from renewable energy sources with a maximum installed capacity of 5 MW is coupled to the amount of the medium-voltage tariff [24,26,28].

4.2. Current photovoltaic status in Bosnia and Herzegovina and the Republic of Srpska

Electricity supplies in Bosnia and Herzegovina are essentially based on coal-fired steam turbine power stations and the exploitation of hydropower. In Bosnia and Herzegovina generally, and the Republic of Srpska particularly, rare are the examples of the use of the PV systems and papers and PV systems studies. In Bosnia and Herzegovina and the Republic of Srpska up to date none PV solar plant has been installed. Currently, the use of grid connected PV systems in Bosnia and Herzegovina comes down to isolated cases installed in public buildings (orphanage, schools…) with demonstration and training purposes. In 2005 the PV installed capacity was estimated at $<1\%$ of total energy supply in Bosnia and Herzegovina by the Commission of the European Communities Research Directorate. Due to a relatively high cost related to the photovoltaic up to this moment the existing facilities are carried out with the support from grants and international projects [24].

One of the first PV systems in Bosnia and Herzegovina was installed and put into service as a part of a project financed by the government of Spain; the system has a total power of 0.32 kW and is used as the energy source for the irrigation system in Popovo Polje, located in Canton K7 and the Republic of Srpska [29].

One of the first PV installations in the Republic of Srpska is being fitted on the roof of an orphanage in Trebinje. The installation is also intended to be used for the training purposes for the local electrical trade [24].

In the Republic of Srpska following feed-in tariffs are in effect:

1. 1 kWh electricity generated by PV solar plants power up to 50 kWp is payed 0.285€.
2. 1 kWh electricity generated by PV solar plants power from 50 kWp to 500 kWp is payed 0.245€ and
3. 1 kWh electricity generated by PV solar plants power over 500 kWp is payed 0.205€.

5. Geographic position and climatic characteristics of the Republic of Srpska

Republic of Srpska is located between 42°33′ and 45°16′ of the north geographic latitude and 16°11′ and 19°37′ of the east longitude and encompasses north and east part of the geo-area

of Bosnia and Herzegovina. Varying climatic influences, affecting the area of the Republic of Srpska, are the result of natural factors and the laws of the overall circulation of the air masses of this area. Thus, on the territory of the Republic of Srpska there are three climatic types: north peri-panonic area with mild continental climate; mountain and mountain–valley climate and a changed variant of the mediterranean–adriatic climate [30] and [31].

5.1. Climatic characteristics of the peri-panonic area of the Republic of Srpska

Peri-panonic area is characterized by the moderate cold winters and hot summers. Values of the mean annual air temperature of this climatic type range from 12 °C to 19 °C. Average monthly air temperature of the hottest month-July ranges from 21 °C to 23 °C, while mean monthly air temperature of the coldest month—January ranges from −0.2 °C to −0.9 °C. Absolute maximal air temperature reaches up to 41 °C while absolute minimal temperature goes up to -30 °C thus making it possible to conclude that annual temperature amplitudes are high and have values up to 71 °C.

On average, annual precipitation is from 1050 l/m^2 on the west to 750 l/m^2 on the east. The biggest precipitation is in the period May–June. Going from the west to the east the precipitation decreases due to the influence of the air streaming, but during the year precipitaion is mainly equally distributed.

This area has around 1900 sunny hours during the year. On the furthest east of the peri-panonic area during winter blows Košava, a cold and cascade wind. Other winds characteristic for this area exist as a consequence of the current air masses circulation [30].

5.2. Characteristics of the mountain and mountain–valley climate of the Republic of Srpska

Mountain and mountain–valley (pre-mountain) variant of the climatic inlfuence is to be found in most parts of the Republic of Srpska. Mountain ranges are characterized by short and chilly summers and cold and snowy winters where snow cover is very high and it stays long.

Mean annual air temperature ranges from 5 °C to 7 °C, mean monthly air temperature in the coldest month—January ranges from 2.5 °C to −3 °C, absolute minimal temperatures reach over −30 °C, and absolute maximal air temperatures reach up to 35 °C. On the basis of these facts it can be concluded that temperature amplitudes are high.

Annual sum of precipitation is over 1200 l/m^2. Number of sunny hours is around 1850, on a yearly basis. In contrast to the mountain climate of these areas hill areas and valleys have somewhat milder climate. Areas with mountain–valley climate have mean annual air temperature around 10 °C, precipitation on an annual basis is around 700–1000 l/m^2 and winters are moderate cold with snow, with frequent temperature inversions and fogs, while summers are moderate hot [30].

5.3. Changed variant of the adriatic climate of the Republic of Srpska

South part of the Republic of Srpska, that is the area of low Herzegovina (which is called Humine) has a changed variant of the adriatic climate, in contrast to the areas of Rudina encompassing higher parts of Herzegovina, which are characterized by the transitive type of climate, something between the climate of Humina and the mountain climate.

Climate of Humina and Rudina is characterized by a weakened inlfuence of the Adriatic Sea. Summers are very hot with around 2400 h of sunshine. Mean annual air temperature ranges from 14 °C and 14.7 °C. Absolute maximal air temperature reaches the value of 41 °C, while absolute minimal air temperature reaches −8 °C. Sum of precipitation ranges from 1500–2000 l/m^2, distribution of precipitation is not favorable, autumn and winter has the biggest and summer the lowest precipitation, and there is draught. These areas have characteristic winds called Bura and Jugo. Bura is a cascade wind of the north and north-east direction, blowing during winter and often reaching the strength of a storm. The wind ugo blows when over Africa there is high pressure and over the Adriatic Sea low air pressure, it blows during the whole year and usually brings rain. In this climatic area the warmest town of the Republic of Srpska, Trebinje, is situated. In contrast to the climate of Humina, climatic characteristics of Rudina are low summer and winter temperatures, and in winter period snow falls are regular [30].

6. Results and discussion

Quantity of sun radiation intake on the surface of earth is influenced by numerous factors such as: geografical latitude of the given place, season of the year, part of the day, purity of the atmosphere, cloudiness, orientation and surface inclination, etc. These data are very important because of their use in calculations of the cost effectiveness of equipment using sun radiation. Very reliable data can be found in data basis PVGIS-a (Photovoltaic Geographical Information System) [2,32–34].

PVGIS (*Photovoltaic Geographical Information System* —PVGIS © European Communities, 2001–2008) is a part of the SOLAREC action aimed at contributing to the implementation of renewable energy in the EU. SOLAREC is an internally funded project on PV solar energy for the 7th Framework Program. PVGIS has been developed at the JRC (Joint Research Centre) of the European Commission within its Renewable Energies Unit since 2001 as a research GIS oriented tool for the performance assessment of solar PV systems in European geographical regions. From the very start of its functioning PVGIS was envisaged to be locally used, however access to the PVGIS database and estimations was drawn as open system access for professionals and the general European public as well, by means of the web-based interactive applications. PVGIS provides data for the analysis of the technical, environmental and socio-economic factors of solar PV electricity generation in Europe and supports systems for EU countries solar energy decision-makings.

PVGIS methodology comprises of solar radiation data, PV module surface inclination and orientation and shadowing effect of the local terrain features (e.g. when the direct irradiation component is shadowed by the mountains), thus PVGIS represents immensely important PV implementation assessment tool that estimates dynamics of the correlations between solar radiation, climate, atmosphere, the earth's surface and the PV technology used. Several fast web applications enable an easy estimation of the PV electricity generation potential for selected specific locations in Europe [2,21,32–34].

The methods used by PVGIS to estimate PV system output have been described in a number of papers. The basis for the European part of PVGIS is a dataset with 10 years of data from 566 ground stations in Europe measuring global horizontal radiation and in some cases diffuses radiation. The station data were collected and processed as a part of the European Solar Radiation Atlas and published as monthly averages of daily irradiation sums [32,35–38].

The construction of high spatial resolution data sets for solar radiation has been previously reported [33,39]. The computational approach is based on a solar radiation model (r.sun), and the spline interpolation techniques (s.surf.rst and s.vol.rst) that are implemented within the open-source GIS software GRASS.

The (r.sun) model algorithm uses the equations published in the European Solar Radiation Atlas. This is certainly a powerful tool that can be used for the development of new solar power plants that will obviate climate change and promote sustainable development through poverty alleviation [37,40,41]. Other details of the PVGIS methodology and development can be found in some key reference papers [35,37,42,43].

In order to calculate electricity generated by the fixed PV solar plants, one-axis and dual-axis tracking PV solar plants today PVGIS software packages easily found on the Internet are used [32,34]. These programs can produce the following data: average daily, monthly and yearly values of the solar irradiation taken on square meter of the horizontal surface, or the surface tilted under certain angle in relation to the horizontal surface, change in the optimal tilting angle of the solar modules during the year, relation of global and diffused sun radiation, average daily temperature, and daily, monthly and yearly electricity generated by the fixed PV solar plants, one-axis and dual-axis tracking PV solar plants, etc. A tipical PVGIS value for the performance ratio (PV system losses) of PV solar plants with modules from monocrystalline and polycrystalline silicon is taken to be 0.75 [2,21,44–47].

This program gives a map which, when appears, activates the program, spots the location of the PV solar plant to be, sorts out the type of solar cells and inputs the power and type of PV solar plant (fixed, one-axis and dual-axis tracking PV solar plants).

In this paper PVGIS-3 is used. The PVGIS-3 data set is based on measurements made on the ground in the period 1981–1990 which are then interpolated between points to get radiation values at any point. A new version PVGIS-CMSAF has been recently introduced which uses the new databases for the solar radiation data provided by the Climate Monitoring Satellite Application Facility (CMSAF) from the period 1998–2010. According to the possible wrong terrestrial measurements and to the fact that the amount of solar radiation has increased over Europe in the last 30 years, calculations performed with new PVGIS-CMSAF give higher values than with the older PVGIS-3 [21,32,35–46]. For the territory of Republic of Srpska PVGIS-CMSAF gives up to 5% higher values for the solar irradiation data [2,21,32].

In this section the results obtained upon the study of the solar irradiation and electricity generated by optimally inclined fixed PV solar plants, optimally inclined one-axis and dual-axis tracking PV solar plants of 1 kW with monocrystalline silicon, CdTe and CIS

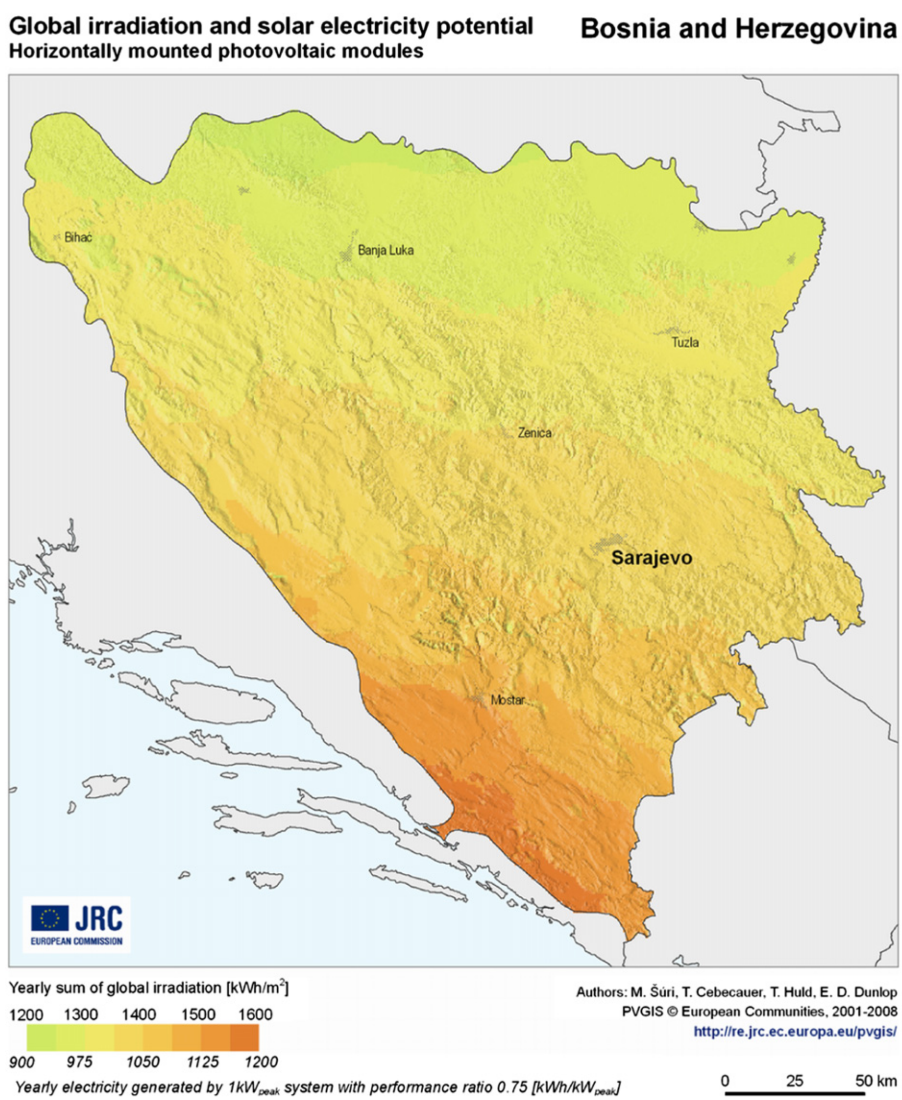

Fig. 2. Yearly sum of total solar irradiation incident on horizontal PV modules in kWh/m^2 and yearly electricity generated by 1 kWp system with performance ratio 0.75 (kWh/kWp) for the territory of Bosnia and Herzegovina obtained by PVGIS. Adapted for Bosnia and Herzegovina from PVGIS©European Communities, 2001–2008, http://re.ec.europa.eu/pvgis/.

solar modules in 13 cities of the Republic of Srpska, processed by the PVGIS program, are given in Ref. [32].

6.1. Solar irradiation in the Republic of Srpska

The aim of this section is to introduce and identify local solar resources in Bosnia and Herzegovina and especially in the Republic of Srpska. Bosnia and Herzegovina can be counted among more favorable locations in Europe with solar irradiation figures on horizontal surface of 1240 kWh/m^2 in the north of the country, and up to 1600 kWh/m^2 in the south [24,28,32]. In Ref. [27] it is given that Bosnia and Herzegovina has on average 1840.9 h of sun annually, while in the south, this number reaches 2352.5 h annually. The theoretical potential for Bosnia and Herzegovina is estimated at around 74.65 PWh, while the technical potential is about 1903 TWh, both of which are substantially more than the energy needs of the country [27].

Yearly sum of the total solar irradiation incident on horizontal PV modules in kWh/m^2 and yearly electricity generated by 1 kWp system with performance ratio 0.75 (kWh/kWp) for the territory of Bosnia and Herzegovina obtained by PVGIS, are given in Fig. 2 [32].

Yearly sum of total solar irradiation incident on optimally inclined south-oriented PV modules in kWh/m^2 and yearly electricity generated by 1 kWp system for the territory of Bosnia and Herzegovina obtained by PVGIS, are given in Fig. 3 [32].

It is clear from Figs. 1 and 2 that average solar irradiation is not dependent on geographical latitude only. There are regional differences in global solar irradiation due to terrain features and climatic conditions.

Geographycal position and the results of PVGIS calculation of the yearly average values of the optimal panel inclination, solar irradiation on the horizontal, optimally inclined and vertical plane, linke turbidity, ratio of diffuse to global solar irradiation, daytime temperature and 24 hours of temperature for some cities in the Republic of Srpska are given in Table 1 [32].

Table 1 shows that:

1. Yearly average of the solar irradiation on horizontal plane ranges from 3450 Wh/m^2 (Derventa) to 4220 Wh/m^2 (Trebinje).

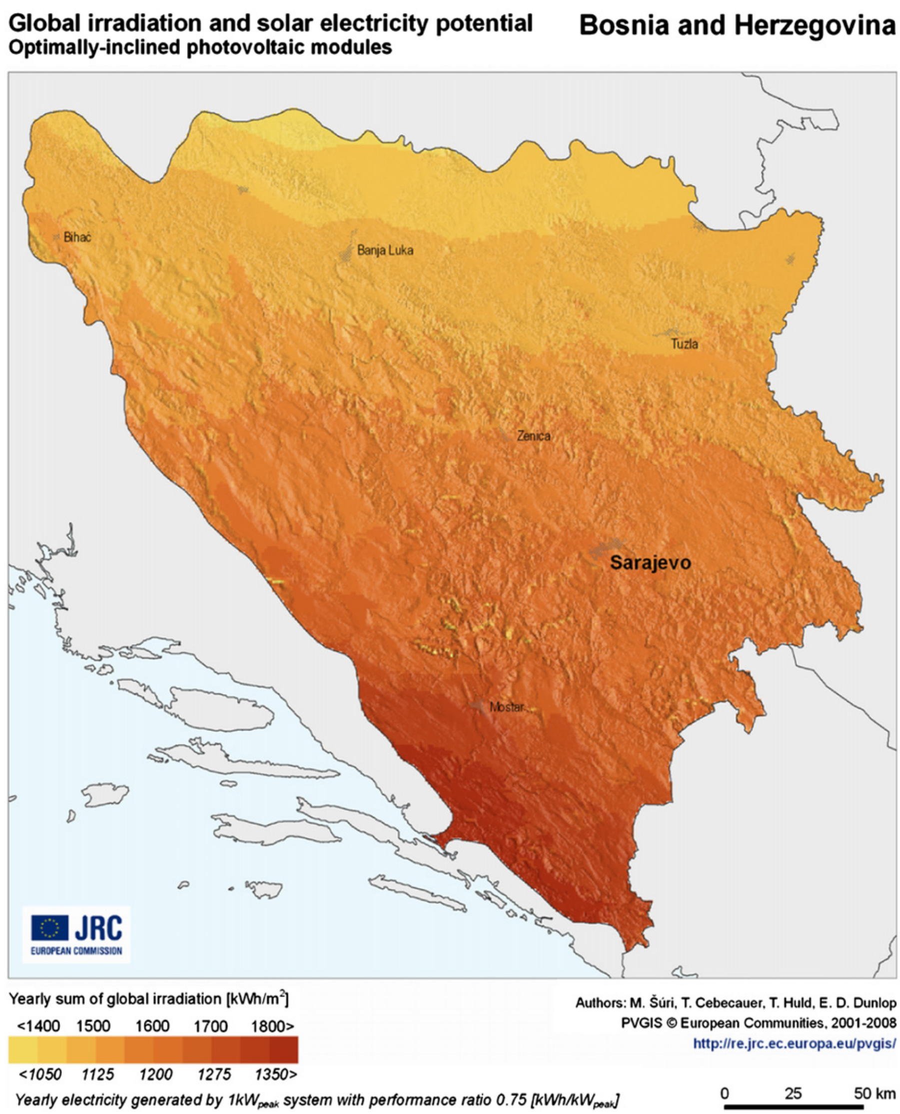

Fig. 3. Yearly sum of total solar irradiation incident on optimally inclined south-oriented PV modules in kWh/m^2 and yearly electricity generated by 1 kWp system for the territory of Bosnia and Herzegovina obtained by PVGIS. Adapted for Bosnia and Herzegovina from PVGIS © European Communities, 2001–2008, http://re.ec.europa.eu/pvgis/.

Table 1
Geographycal position and the results of PVGIS calculation of the yearly average values of the optimal panel inclination, solar irradiation on the horizontal, optimally inclined and vertical plane, linke turbidity, ratio of diffuse to global solar irradiation, daytime temperature and 24 h of temperature for some cities in the Republic of Srpska are given in Table 1 [32].

Some cities in Republik Srpska	Geographical position	Optimal panel inclination (°)	Solar irradiation			Linke turbidity	Ratio of diffused and global solar radiation	Average daytime temperature (°C)	24 hour average of temperature (°C)
			On horizontal plane (Wh/m^2)	On optimally inclined plane (Wh/m^2)	On vertical plane (Wh/m^2)				
Novi Grad Annual irradiation deficit due to shadowing (horizontal): 0.1%	45°2′43″ nort latitude and 16°23′4″ east longitude	34	3500	3960	2620	3.8	0.50	13.4	12.0
Derventa Annual irradiation deficit due to shadowing (horizontal): 0.0%	44°58′51″ nort latitude and 17°54′34″ east longitude	33	3450	3900	2580	3.5	0.50	13.3	12.0
Prijedor Annual irradiation deficit due to shadowing (horizontal): 0.0%	44°58′44″ nort latitude and 16°42′13″ east longitude	34	3500	3980	2640	3.7	0.49	13.6	12.3
Brčko Annual irradiation deficit due to shadowing (horizontal): 0.0%	44°52′11″ nort latitude and 18°48′35″ east longitude	34	3520	3990	2650	3.2	0.49	13.3	12.1
Bijeljina Annual irradiation deficit due to shadowing (horizontal): 0.0%	44°45′0″ nort latitude and 19°13′0″ east longitude	34	3560	4040	2690	3.1	0.49	13.4	12.1
Banja Luka Annual irradiation deficit due to shadowing (horizontal): 0.0%	44°46′0″ nort latitude and 17°10′59″ east longitude	34	3540	4010	2660	3.7	0.50	13.1	11.8
Doboj Annual irradiation deficit due to shadowing (horizontal): 0.2%	44°44′26″ nort latitude and 18°5′34″ east longitude	34	3530	4000	2650	3.4	0.50	12.9	11.7
Zvornik Annual irradiation deficit due to shadowing (horizontal): 3.9%	44°23′30″ nort latitude and 19°6′20″ east longitude	33	3480	3930	2570	3.3	0.50	13.0	11.9
Pale Annual irradiation deficit due to shadowing (horizontal): 0.1%	43°49′0″ nort latitude and 18°34′0″ east longitude	35	3770	4350	2920	3.4	0.46	9.8	8.8
Sarajevo Annual irradiation deficit due to shadowing (horizontal): 0.1%	43°50′51″ nort latitude and 18°21′23″ east longitude	35	3800	4380	2930	3.5	0.45	12.2	11.1
VišegradAnnual irradiation deficit due to shadowing (horizontal): 0.6%	43°47′7″ nort latitude and 19°17′35″ east longitude	34	3740	4270	2820	3.3	0.46	12.4	11.3
Foča Annual irradiation deficit due to shadowing (horizontal): 0.4%	43°30′14″ nort latitude and 18°46′41″ east longitude	35	3850	4430	2950	3.5	0.46	11.4	10.3
Trebinje Annual irradiation deficit due to shadowing (horizontal): 0,2%	42°42′40″ nort latitude and 18°20′33″ east longitude	35	4220	4890	3240	3.4	0.41	14.1	12.9

2. Yearly average of the solar irradiation on optimally inclined plane ranges from 3930 Wh/m^2 (Zvornik) to 4890 Wh/m^2 (Trebinje).
3. Yearly average of the solar irradiation on vertical plane ranges from 2570 Wh/m^2 (Zvornik) to 3240 Wh/m^2 (Trebinje).
4. Yearly average of the optimal panel inclination ranges from 33° (Derventa, Zvornik) to 35° (Pale, Sarajevo, Foča, Trebinje).
5. Yearly average of the linke turbidity ranges from 3.1 (Bijeljina) to 3.8 (Novi Grad).
6. Yearly average of the ratio diffuse to global solar irradiation ranges from 0.41 (Trebinje) to 0.50 (Novi Grad, Derventa, Banja Luka, Doboj, Zvornik).
7. Yearly average of the daytime temperature ranges from 9.8 °C (Pale) to 14.1 (Trebinje) and
8. Yearly average of the 24 h temperature ranges from 8.8 °C (Pale) to 12.9 (Trebinje).

Total for year sum of global irradiation per square meter received by the modules of the given PV system (optimally inclined fixed PV solar plants, optimally inclined one-axis and dual-axis tracking PV solar plants) of 1 kW in some cities in the Republic of Srpska, obtained by PVGIS, is given in Table 2 [32].

Table 2 shows that:

1. Total for year sum of global irradiation per square meter received by the optimally inclined fixed PV solar plants of 1 kW ranges from 1420 kWh (Derventa) to 1780 kWh (Trebinje).
2. Total for year sum of global irradiation per square meter received by the optimally inclined one-axis tracking PV solar plants of 1 kW ranges from 1670 kWh (Zvornik) to 2290 kWh (Trebinje).
3. Total for year sum of global irradiation per square meter received by the dual-axis tracking PV solar plants of 1 kW ranges from 1720 kWh (Zvornik) do 2360 kWh (Trebinje).
4. In Zvornik optimally inclined one-axis tracking PV solar plants of 1 kW intake 16.78% more solar irradiation compared to optimally inclined fixed PV solar plant of 1 kW, and dual-axis tracking PV solar plants of 1 kW intake 20.28% more solar irradiation compared to optimally inclined fixed PV solar plant of 1 kW and dual-axis tracking PV solar plants of 1 kW intake 2.99% more solar irradiation compared to optimally inclined one-axis tracking PV solar plants of 1 kW and
5. In Trebinje optimally inclined one-axis tracking PV solar plants of 1 kW intake 28.65% more solar irradiation than optimally

inclined fixed PV solar plant of 1 kW, dual-axis tracking PV solar plants of 1 kW intake 32.58% more solar radiation than optimally inclined fixed PV solar plant of 1 kW and dual-axis tracking PV solar plants of 1 kW intake 3.06% more solar irradiation than optimally inclined one-axis tracking PV solar plants of 1 kW.

6.2. Electricity production of different types of PV solar plant of 1 kW in 13 cities in the Republic of Srpska

The total for year electricity production of different types of PV solar plant of 1 kW in some cities in the Republic of Srpska, obtained by PVGIS, is given in Table 3 [32].

Table 3 shows that:

1. Irrespectable of the type of PV solar plants most electrical energy is generated if CdTe solar cells are used.
2. Total for year electricity production by the optimally inclined fixed PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1070 kWh (Derventa, Zvornik) to 1350 kWh (Trebinje), with CdTe solar modules from 1190 kWh (Derventa) to 1490 kWh (Trebinje) and with CIS solar modules from 1090 kWh (Derventa) to 1370 kWh (Trebinje).
3. Total for year electricity production by the optimally inclined one-axis tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1250 kWh (Zvornik) to 1740 kWh (Trebinje), with CdTe solar modules from 1380 kWh (Zvornik) to 1900 kWh (Trebinje) and with CIS solar modules from 1290 kWh (Zvornik) to 1780 kWh (Trebinje) and
4. Total for year electricity production by the dual-axis tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1280 kWh (Zvornik) to 1780 kWh (Trebinje), with CdTe solar modules from 1410 kWh (Zvornik) to 1950 kWh (Trebinje) and with CIS solar modules from 1310 kWh (Zvornik) to 1820 kWh (Trebinje).

Estimated losses in PV solar plants of 1 kW in some cities in the Republic of Srpska, obtained by PVGIS, are given in Table 4 [32].

Comparison of the total for year electricity production of different types of PV solar plant with monocrystaline silicon solar modules of 1 kW in some cities in the Republic of Srpska is shown in Fig. 4.

Fig. 4 shows that

1. In Zvornik by means of dual-axis tracking PV solar plant of 1 kW with solar modules of monocrystalline silicon 19.63% more electrical energy is generated compared to optimally inclined fixed PV solar plant of 1 kW with solar modules of monocrystalline silicon and 2.4% more electrical energy is generated than in the case of optimally inclined one-axis

Table 2
Total for year sum of global irradiation per square meter received by the modules of the given PV system (optimally inclined fixed PV solar plants, optimally inclined one-axis and dual-axis tracking PV solar plants) of 1 kW in some cities in the Republic of Srpska obtained by PVGIS [32].

Some cities of Republic of Srpska	Total for year sum of global irradiation per square meter received by the modules of the optimally inclined fixed PV solar plant of 1 kW (kWh/m^2)	Total for year sum of global irradiation per square meter received by the modules of the optimally inclined one-axis tracking pv solar plant of 1 kW (kWh/m^2)	Total for year sum of global irradiation per square meter received by the modules of the dual-axis tracking PV solar plant of 1 kW (kWh/m^2)
Novi Grad	1440	1790	1840
Derventa	1420	1780	1830
Prijedor	1450	1820	1870
Brčko	1450	1850	1890
Bijeljina	1480	1890	1930
Banja Luka	1460	1830	1880
Doboj	1460	1810	1860
Zvornik	1430	1670	1720
Pale	1590	2010	2070
Sarajevo	1600	2040	2100
Višegrad	1560	1940	1990
Foča	1620	2000	2060
Trebinje	1780	2290	2360

Table 3
Total for year electricity production of different types of PV solar plant of 1 kW to some cities in the Republic of Srpska [32].

Some cities of the Republic of Srpska	Total for year electricity production from the optimally inclined fixed PV solar plant of 1 kW (kWh)			Total for year electricity production from the optimally inclined one-axis tracking PV solar plant of 1 kW (kWh)			Total for year electricity production from the dual-axis tracking PV solar plant of 1 kW (kWh)		
	c-Si solar modules	CdTe solar modules	CIS solar modules	c-Si solar modules	CdTe solar modules	CIS solar modules	c-Si solar modules	CdTe solar modules	CIS solar modules
Novi Grad	1090	1210	1110	1360	1490	1390	1390	1530	1420
Derventa	1070	1190	1090	1360	1490	1390	1380	1520	1420
Prijedor	1100	1220	1120	1390	1520	1420	1420	1560	1450
Brčko	1100	1200	1120	1400	1510	1430	1430	1540	1460
Bijeljina	1110	1230	1130	1430	1560	1460	1460	1600	1490
Banja Luka	1110	1230	1130	1400	1530	1420	1430	1560	1460
Doboj	1100	1220	1120	1370	1500	1410	1400	1540	1440
Zvornik	1070	1200	1100	1250	1380	1290	1280	1410	1310
Pale	1220	1330	1240	1550	1670	1580	1590	1710	1620
Sarajevo	1220	1340	1240	1560	1700	1590	1600	1740	1630
Višegrad	1180	1300	1200	1470	1610	1500	1500	1640	1540
Foča	1240	1350	1260	1530	1670	1560	1570	1710	1600
Trebinje	1350	1490	1370	1740	1900	1780	1780	1950	1820

Table 4
Estimated losses in PV solar plants of 1 kW in some cities in the Republic of Srpska, obtained by PVGIS [32].

Some cities in Republic of Srpska	Estimated losses due to temperature (using local ambient temperature) on			Estimated loss due to angular reflectance effects on			Other losses (cables, inverter etc.)			Combined PV system losses on		
	c-Si solar modules (%)	CdTe solar modules (%)	CIS solar modules (%)	c-Si solar modules (%)	CdTe solar modules (%)	CIS solar modules (%)	c-Si solar modules (%)	CdTe solar modules (%)	CIS solar modules (%)	c-Si solar modules (%)	CdTe solar modules (%)	CIS solar modules (%)
Novi Grad	9.2	−0.3	7.7	2.8	2.8	2.8	14	14	14	24.1	16.2	22.8
Derventa	9.3	−0.1	7.8	2.9	2.9	2.9	14	14	14	24.2	16.3	22.9
Prijedor	9.2	−0.2	7.7	2.8	2.8	2.8	14	14	14	24.1	16.3	22.9
Brčko	9.4	1.2	7.9	2.9	2.9	2.9	14	14	14	24.4	17.5	23.1
Bijeljina	9.5	0.2	8.0	2.9	2.9	2.9	14	14	14	24.4	16.7	24.4
Banja Luka	9.1	−0.2	7.6	2.8	2.8	2.8	14	14	14	24.0	17.3	22.8
Doboj	9.2	−0.1	7.7	2.8	2.8	2.8	14	14	14	24.2	16.4	22.8
Zvornik	10.3	0.4	8.4	2.6	2.6	2.5	14	14	14	24.9	16.5	23.2
Pale	7.9	−0.1	6.4	2.7	2.7	2.7	14	14	14	23.0	16.2	21.8
Sarajevo	8.8	0.0	7.3	2.7	2.7	2.7	14	14	14	23.7	16.3	22.4
Višegrad	9.2	0.1	7.5	2.7	2.7	2.7	14	14	14	24.0	16.4	22.6
Foča	8.4	−0.2	6.9	2.7	2.7	2.7	14	14	14	23.4	16.1	22.1
Trebinje	9.5	0.3	7.8	2.7	2.7	2.7	14	14	14	24.2	16.5	22.9

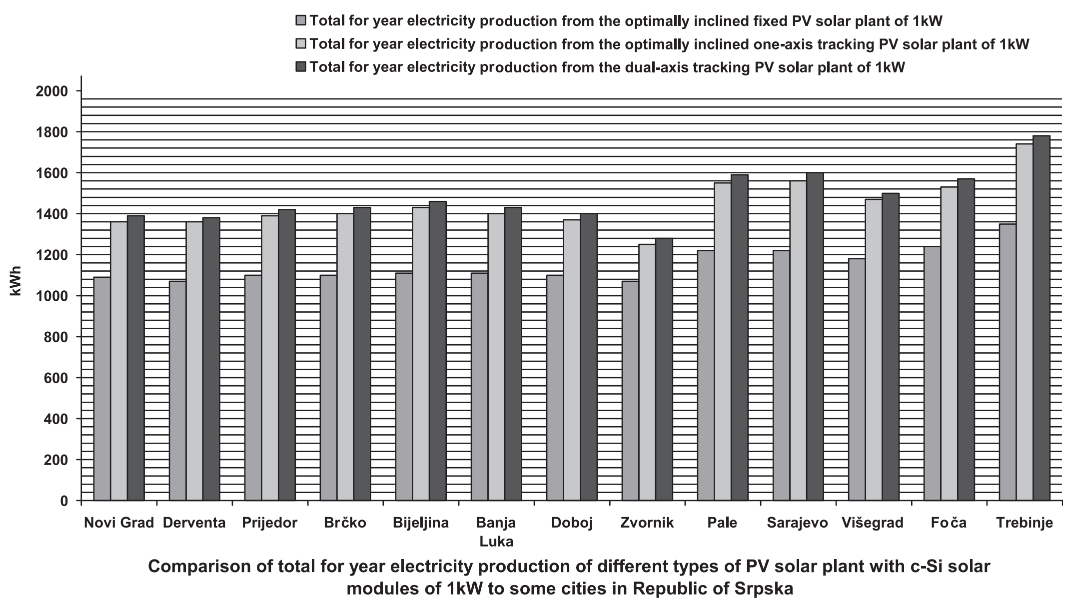

Fig. 4. Comparison of the total for year electricity production of different types of PV solar plant with monocrystaline silicon solar modules of 1 kW in some cities in the Republic of Srpska.

tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon and

2. In Trebinje by means of dual-axis tracking PV solar plant of 1 kW with solar modules of monocrystalline silicon 31.85% more electrical energy is generated compared to optimally inclined fixed PV solar plant of 1 kW with solar modules of monocrystalline silicon and 2.29% more electrical energy is generated than by means of the optimally inclined one-axis tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon.

Comparison of the total for year electricity production of different types of PV solar plant with CdTe solar modules of 1 kW in some cities in the Republic of Srpska is shown in Fig. 5.

Fig. 5 shows that

1. In Zvornik by means of dual-axis tracking PV solar plant of 1 kW with CdTe solar modules 17.5% more electrical energy is generated than in the case of optimally inclined fixed PV solar plant of 1 kW with CdTe solar modules and 2.17% more electrical energy in comparison to the optimally inclined one-axis tracking PV solar plants of 1 kW with CdTe solar modules and
2. In Trebinje by means of dual-axis tracking PV solar plant of 1 kW with CdTe solar modules 30.87% more electrical energy is generated than by optimally inclined fixed PV solar plant of 1 kW with CdTe solar modules and 2.63% more electrical energy is generated than by the optimally inclined one-axis tracking PV solar plants of 1 kW with CdTe solar modules.

Comparison of the total for year electricity production of different types of PV solar plant with CIS solar modules of 1 kW in some cities in the Republic of Srpska is shown in Fig. 6.

Fig. 6 shows that

1. In Zvornik by means of dual-axis tracking PV solar plant of 1 kW with CIS solar modules 19.09% more electrical energy is generated than by the optimally inclined fixed PV solar plant

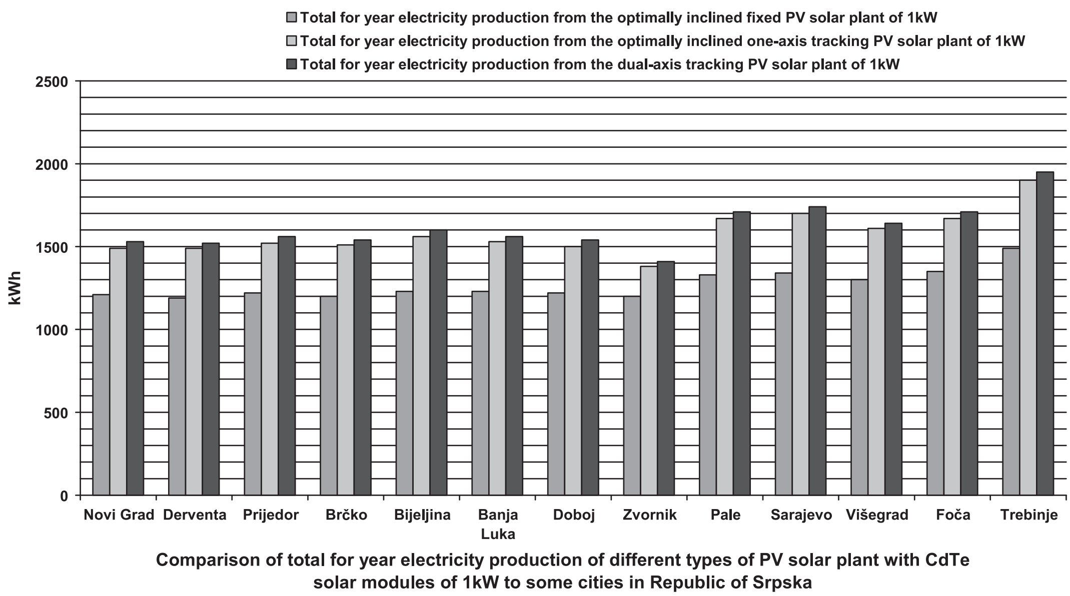

Fig. 5. Comparison of the total for year electricity production of different types of PV solar plant with CdTe solar modules of 1 kW in some cities in the Republic of Srpska.

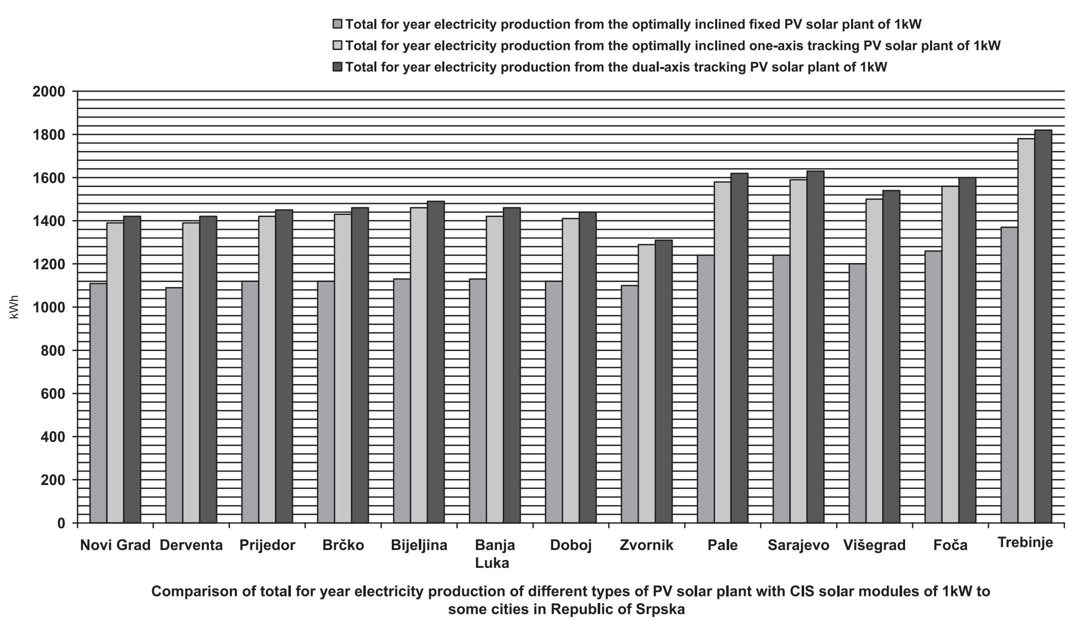

Fig. 6. Comparison of the total for year electricity production of different types of PV solar plant with CIS solar modules of 1 kW in some cities in the Republic of Srpska.

of 1 kW with CIS solar modules and 1.55% more electrical energy is generated than by the optimally inclined one-axis tracking PV solar plants of 1 kW with CIS solar modules and

2. In Trebinje by means of dual-axis tracking PV solar plant of 1 kW with CIS solar modules 32.85% more electrical energy is generated than by the optimally inclined fixed PV solar plant of 1 kW with CIS solar modules and 2.25% more electrical energy is generated than by the optimally inclined one-axis tracking PV solar plants of 1 kW with CIS solar modules.

7. Conclusion

Global Warming is caused by many things, pollution being one of the biggest man-made problems. Burning fossil fuels give off a green house gas called CO_2. To avoid pollution most countries will be forced to use renewable sources energy coming from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished) to meet their needs for the energy. Solar energy is one of the best renewable energy sources. The main purpose of the research, development and use of solar energy is that the use of solar energy contributes to more efficient use of the countries own potentials in generating electrical and thermal energy, reduction of "the green house effects" emission, reduction of the import and use of the fossil fuels, development of the local industry and new job openings. Solar powered electrical generation relies on photovoltaics and heat engines. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar

techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy.

In the light of all afore mentioned one can conclude that nowadays worldwide PV solar plants use mainly solar cells made of monocrystalline, polycrystalline and amorphous silicon, CdTe and CIS solar cells. Based on climate and other conditions fixed, one-axis, and dual-axis tracking PV solar plants are installed worldwide.

Although the Republic of Srpska has very favorable climate and legal conditions for the installation and use of PV solar plants, up to now not one PV solar plant has been installed and there are rare cases of the use of PV systems elsewhere.

Spanish government has financed a PV system, total power of 0.32 kW in Bosnia and Herzegovina, installed as a part of the project. It is being used as the energy source for the irrigation system in Popovo Polje, located in Canton K7 and the Republic of Srpska. This first PV installation in the Republic of Srpska is roof-installed in the orphanage in Trebinje.

Application of PVGIS program in 13 towns in the Republic of Srpska shows that yearly average of the optimal panel inclination ranges from 33° to 35°; total for year sum of global irradiation per square meter received by the optimally inclined fixed PV solar plants of 1 kW ranges from 1420 kWh (Derventa) to 1780 kWh (Trebinje); total for year sum of global irradiation per square meter received by the optimally inclined one-axis tracking PV solar plants of 1 kW ranges from 1670 kWh (Zvornik) to 2290 kWh (Trebinje); total for year sum of global irradiation per square meter received by the dual-axis tracking PV solar plants of 1 kW ranges from 1720 kWh (Zvornik) to 2360 kWh (Trebinje).

Total for year electricity production by the optimally inclined fixed PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1070 kWh (Derventa, Zvornik) to 1350 kWh (Trebinje), with CdTe solar modules ranges from 1190 kWh (Derventa) to 1490 kWh (Trebinje) and with CIS solar modules it ranges from 1090 kWh (Derventa) to 1370 kWh (Trebinje).

Total for year electricity production by the optimally inclined one-axis tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1250 kWh (Zvornik) to 1740 kWh (Trebinje), with CdTe solar modules it ranges from 1380 kWh (Zvornik) to 1900 kWh (Trebinje) and with CIS solar modules from 1290 kWh (Zvornik) to 1780 kWh (Trebinje).

Total for year electricity production by the dual-axis tracking PV solar plants of 1 kW with solar modules of monocrystalline silicon ranges from 1280 kWh (Zvornik) to 1780 kWh (Trebinje), with CdTe solar modules from 1410 kWh (Zvornik) to 1950 kWh (Trebinje) and with CIS solar modules from 1310 kWh (Zvornik) to 1820 kWh (Trebinje).

Irrespectable of the type of PV solar plants, PVGIS program has shown that most electrical energy in the Republic of Srpska can be generated by PV solar plants with CdTe solar cells.

Acknowledgment

This paper was done with the financial support of the project TR 33009 approved by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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